CENTRE NATIONAL D'ETUDES SPATIALES

Orlando

March 25-27, 2003

CNES Position Regarding the Use of the X- and Ka- Bands for EESS

Frédéric Cornet

Centre National d'Etudes Spatiales

(Frederic.Cornet@cnes.fr)

CENTRE NATIONAL D'ETUDES SPATIALES

Data Rates Requirements

Future earth observation space missions are based

on high resolution or large field optical and radar sensors

=> larger and larger amount of data are produced on-board satellites

Use of data compression mandatory,

but users want quasi-lossless compression

=> low compression ratio (between 3 to 6) only

=> high quality BER (Bit Error Rate) and FER (Frame Error Rate) required

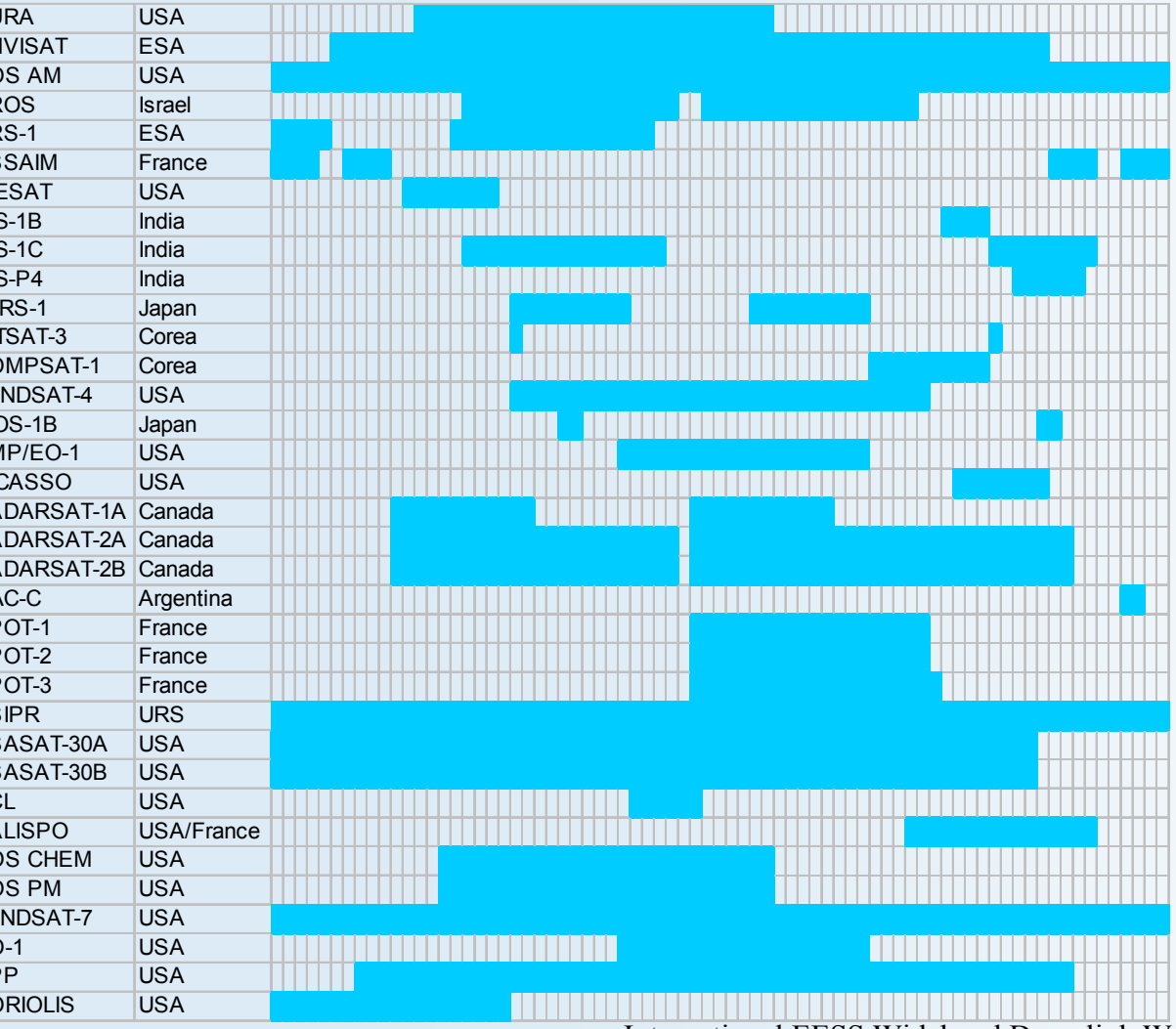
$< 10^{-10}$ **$< 10^{-7}$**

down-link data rates are increasing

but are limited by cost, mass and consumption

CENTRE NATIONAL D'ETUDES SPATIALES

Frequency Allocation



S-Band

available for low data rates

(< 2MBps)

X-Band (8025 - 8400 MHz)

used by most of the data

telemetry payloads

Ka-Band (25.5 - 27 GHz)

allocated during WRC'97

CENTRE NATIONAL D'ETUDES SPATIALES

Interference in X-Band

Two kinds of interference can occur :

- **In-band emissions interfere with other spacecraft using a part of the 8025-8400MHz band => degradation of both service**
  - geographic diversity of ground stations may help
  - spectrally-efficient coding and modulation may help
  - orbital coordination of EESS may help (like for GEO : frequency and position are jointly assigned)
  - Use of pointing on-board antenna
  - Migration to Ka-Band has to be considered
- **Out-of-band emissions interfere with other services using adjacent frequency bands => degradation of the other service (DSN for example)**
  - Filtered transmission can highly reduce the interference on other services
  - Use of pointing on-board antenna

CENTRE NATIONAL D'ETUDES SPATIALES

In-Band Interference

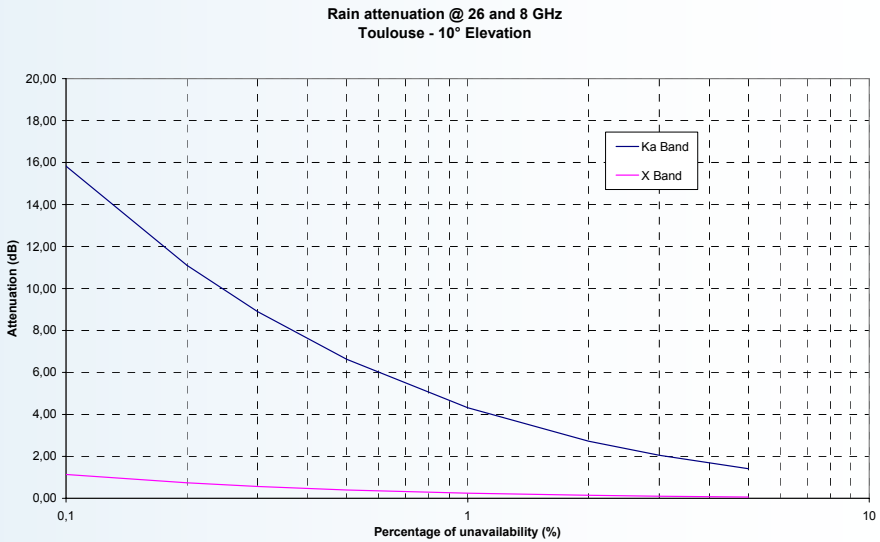
CNES has explored some ways to reduce interference in X-Band :

- **Direct downlink in Ka-Band (25.5 - 27GHz)**
- **Inter-satellite link (to a relay hosted by a GEO)**
- **Use of large antenna for the ground stations**
- **Use of pointing on-board antenna**
- **Spectrally-efficient coding & modulation schemes**

CENTRE NATIONAL D'ETUDES SPATIALES

Direct downlink at Ka-Band

Use of the 25.5-27GHz Band



- **Propagation impairments**
  - free space losses
  - atmospheric gases, rain attenuation
- **Hardware**
  - ground station antenna : gain increases
  - on-board antenna
    - quasi iso flux ⇒ very low data rates, no ground station in rainy region
    - **pointing** ⇒ high data rates, link budget ensured everywhere, some mission constraints
  - On-board amplifier : prototype developed by Thales (30W and 60W TWTA)
  - Increase of the phase noise
  - For some mission, it is **impossible** to track the satellite only **after 10° elevation** instead of 5° because of the resultant decrease of the number of crossing

CENTRE NATIONAL D'ETUDES SPATIALES

Inter-Satellite Link

Use of Ka-Band, 60GHz Band or optical link between the Earth Exploration Satellite and a geostationary satellite.

- No constraint on data flow congestion
- Improvement of mission performance
- **High complexity of the space segment**
- **High cost of the system development**

CNES study in 2002 :

- Use of a Ka-Band link with a GEO for 10% of mission data

Application in Europe :

- Silex, an optical link between Spot IV and Artemis
- Ka-band link between Envisat and Artemis

CENTRE NATIONAL D'ETUDES SPATIALES

Ground stations

High latitude : nearly 12 crossings per day

- Esrange Satellite Station (Kiruna, Sweden) : *"We have not faced any problems on the X-band reception that has been related to interference from other satellites"*
- Need to use large antenna ⇒ narrow main and second lobes

Low latitude : nearly 5 crossings per day

- 3.5 m ground station used in Toulouse
- No data loss due to X-Band interference in Toulouse since 1986
- 5.4 m direct receiving stations all around the world (about 20 customers)

Use of broadcasting

- Highly increase probability of interference
- Transmission should be limited to periods when transmitting data to Earth stations (SFCG Rec 14-3R4)

CENTRE NATIONAL D'ETUDES SPATIALES

Use of spectrally-efficient encoding & modulation schemes

Bandwidth is a scarce resource : a better use than today's one is necessary

⇒ **Improve spectral efficiency over 1 bit/s/Hz**

(actual common value)

Use of 8PSK modulation ⇒ Spectral occupation reduction of 1.25

(with 2.5/3 code rate versus RS coded QPSK)

Modulation	Efficiency (bits/symb)	Filtered efficiency (bits/s/Hz)
QPSK, RS coded	1.87	1.19
8PSK, RS + trellis 2/3	1.87	1.19
8PSK, RS + trellis 2.5/3	2.34	1.49

Note : this can be also considered as a 2.7 dB link budget improvement vs a RS coded QPSK modulation @ BER = 10^{-9}

CENTRE NATIONAL D'ETUDES SPATIALES

8PSK On-Board Transmitter

Compact Size :
250 (with internal connection)
x 105 x 90 mm

Mass : around **1.4 kg**

Consumption : around **30 W**

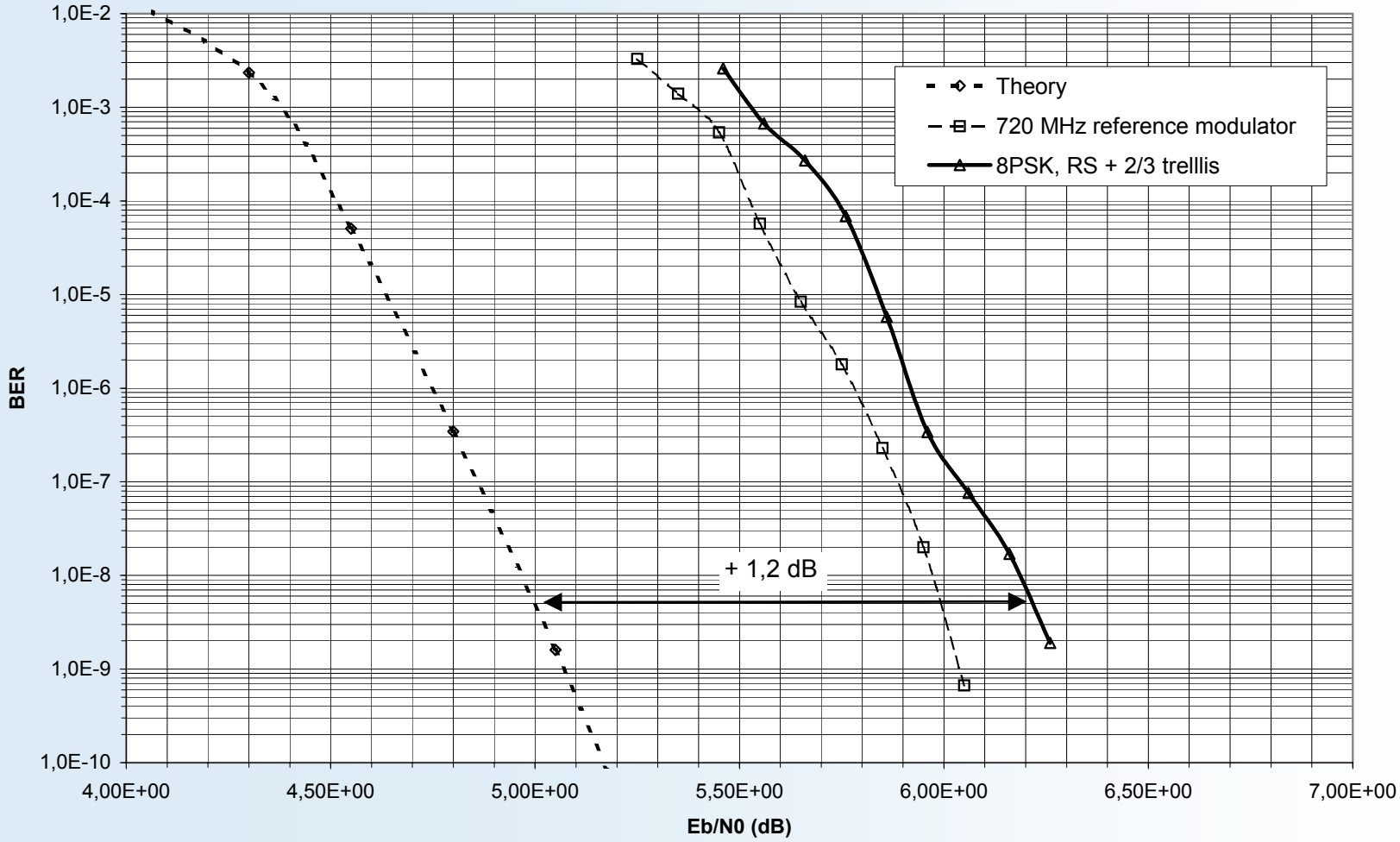
Effective Data Rate :
from 16.8 Mb/s
up to 160 Mb/s

Output Power : **8 dBW (EOL)**

Failure Rate : **< 700 Fits @ 40°C**

CENTRE NATIONAL D'ETUDES SPATIALES

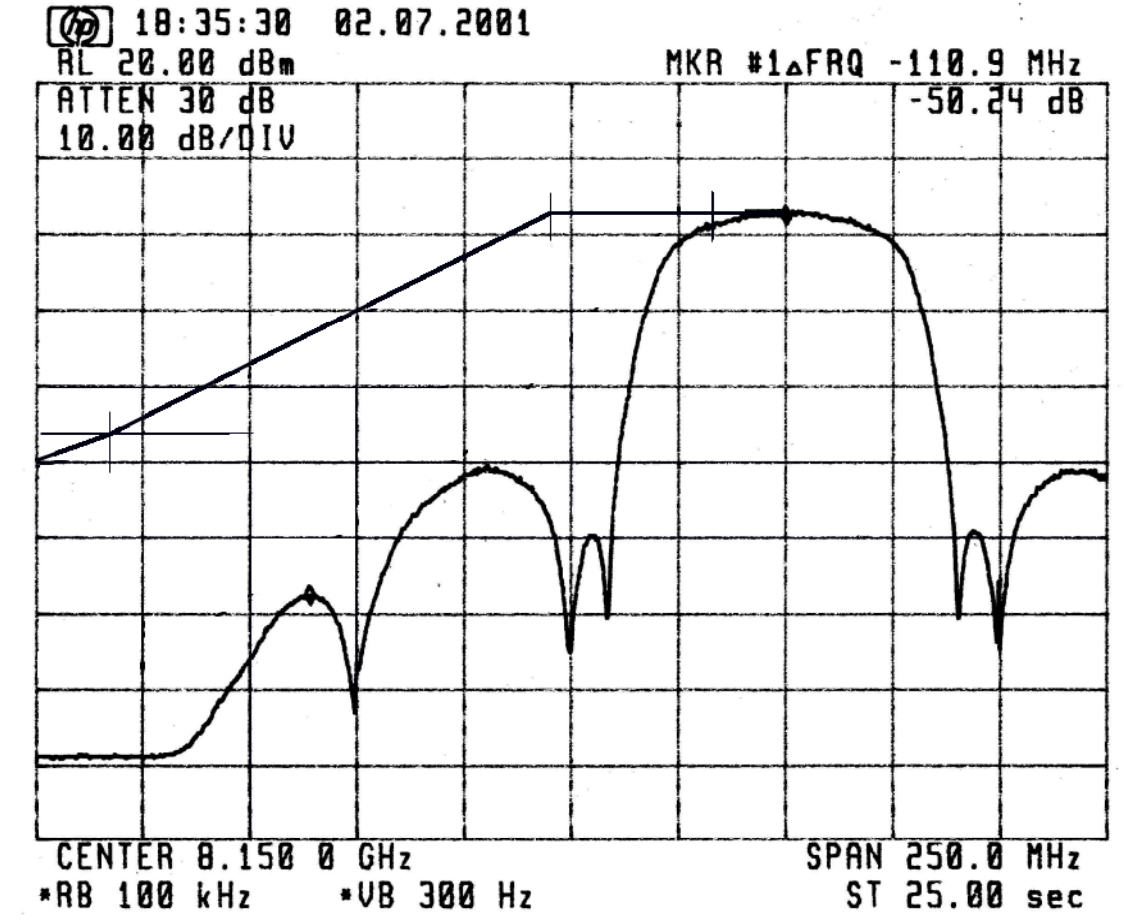
Modem measured performance



CENTRE NATIONAL D'ETUDES SPATIALES

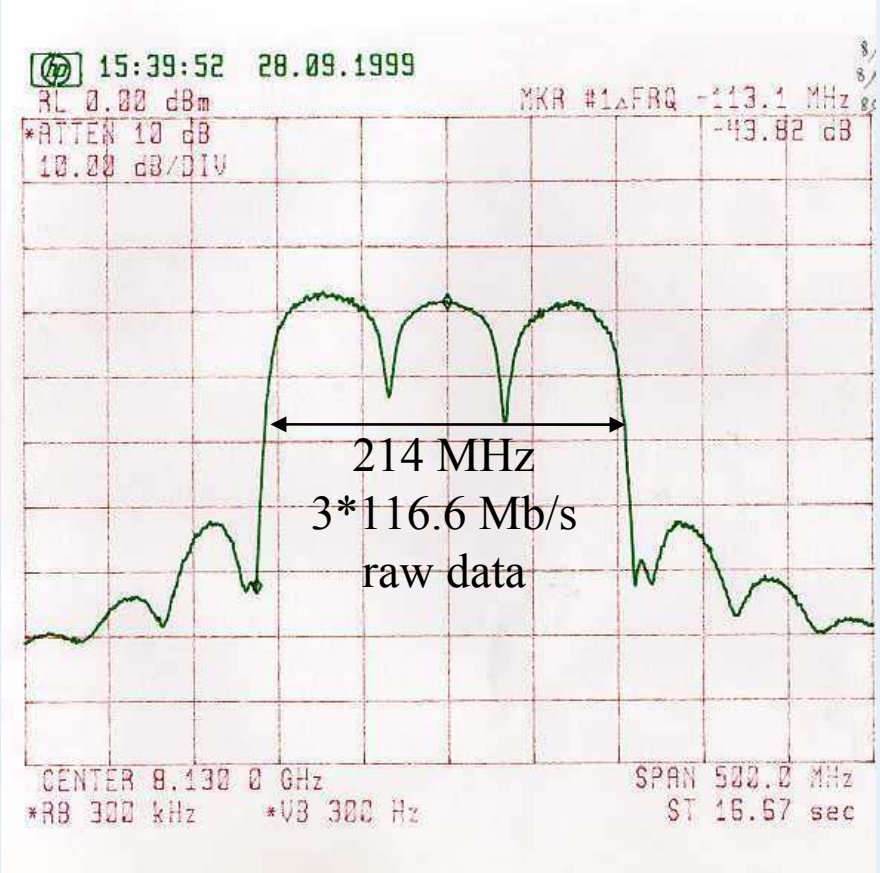
Output Spectrum at 50 MBauds

CCSDS 17-2R1

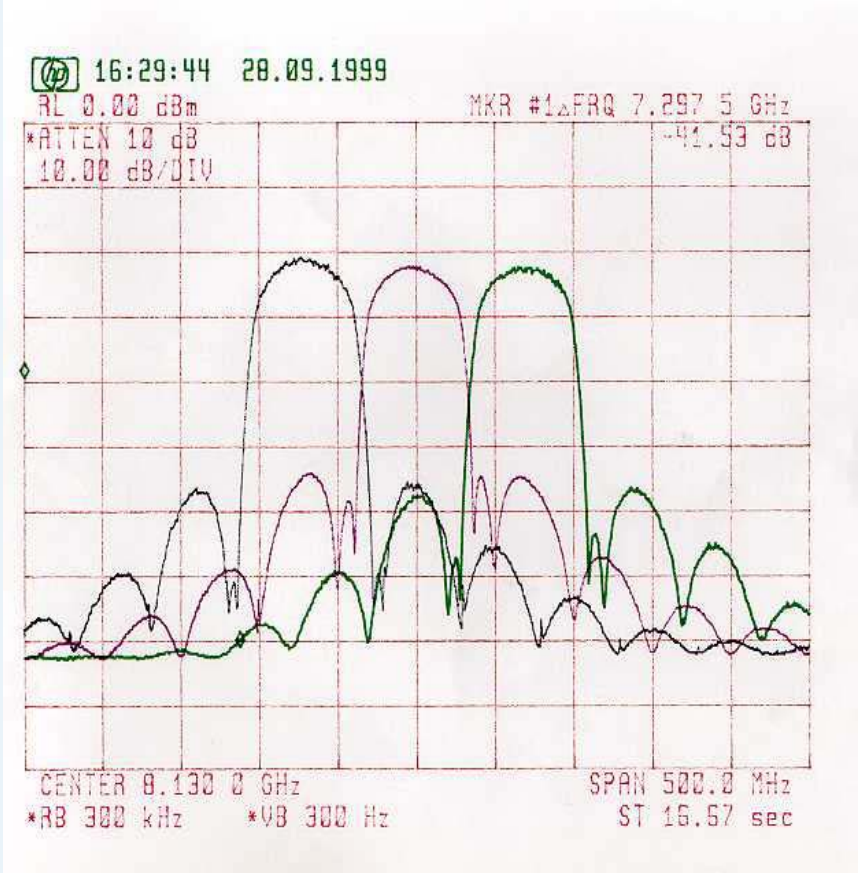


CENTRE NATIONAL D'ETUDES SPATIALES

Spectra in quasi-SSRC multi-channel



3 channels at the OMUX output



The 3 channels combination

CENTRE NATIONAL D'ETUDES SPATIALES

CCSDS Recommendation

CCSDS 401.0-B "Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft" (June 2001) recommends

that a mission planning to use conventional modulation methods which have an occupied bandwidth exceeding that permitted by the SFCG for the 8025-8400 MHz band, use 4D 8PSK TCM, provided that in no case shall the occupied bandwidth of said mission exceed that permitted by the SFCG

(2.4.18 : MODULATION METHODS AT HIGH SYMBOL RATES TRANSMISSIONS, EARTH EXPLORATION SATELLITES 8 GHZ BAND, SPACE-TO EARTH)

CENTRE NATIONAL D'ETUDES SPATIALES

Use of spectrally-efficient encoding & modulation schemes

Applications of 8PSK modulation : on-going programs

- **CNES Demeter program**
  - Detection of electro-magnetic emissions and earth radioelectric activity survey
  - 8PSK/6.3W transmitter associated with a 3.5dBi isoflux antenna
  - Protoflight models of the transmitter and the antenna delivered in 2002
  - Satellite launch planned in 2004

- **CNES Pleiades program**
  - Earth optical observation - Sub metric resolution
  - Three 8PSK/30W transmitters, a steep edges OMUX and quasi iso-flux antenna
  - Development of a 3 channels demonstrator to be tested end 2003
  - Protoflight models to be delivered mid 2004

CENTRE NATIONAL D'ETUDES SPATIALES

Use of spectrally-efficient encoding & modulation schemes

Applications of 8PSK modulation : future programs

- **Micro-satellite series for scientific and technologic programs**
  - Parasol (launch in 2004)
  - More than ten micro-satellites using 8PSK TCM telemetry will be launched during the next decade
- **Multi missions scientific programs such as ESA's SMOS program**

for additional information on 4D 8PSK TCM, contact Dr. Lesthievent (Guy.Lesthievent@cnes.fr)

CENTRE NATIONAL D'ETUDES SPATIALES

CNES point of view

Today, no interference has been observed by CNES in the X-Band.

- Need to quantify with accuracy probability of interference between future Earth Exploration missions

Channelization of the 8025-8400 MHz

- certainly one of the worst way to use efficiently the band
- Need to consider separately the high and low latitude Earth station

Today, two simple solutions can be applied on the future missions

- Orbital/time coordination between agencies
- Do not use broadcasting mode

If high data rate is needed, CNES recommends to use 4D 8PSK TCM in order to reduce band occupancy and interference

CENTRE NATIONAL D'ETUDES SPATIALES

Future works

Computation of interference

- participation in the X-Band IWG (SFCG)
- Computation of interference and probability of interference with Matlab
- Accurate models in order to compute a worst case that can occur !

Spectrally-efficient modulation & coding

- High priority for CNES
- First flight planned in 2004

Direct downlink in Ka-Band

- No mission planned and no funds

Inter-Satellite Link

- No mission planned and no funds